NASA High Performance Computing and Communications Program

Computational Aerospace Sciences Project Plan

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Computational Aerospace Sciences Project Plan

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COMPUTATIONAL AEROSPACE SCIENCES PROJECT PLAN

1. INTRODUCTION

1.1 Introduction

This document is the Project Plan for the Computational Aerospace Sciences (CAS) Project of NASA's High Performance Computing and Communications (HPCC) Program. It is consistent with HPCC Program Plan and the President's FY2001 budget. It is consistent with the normal procedures used by the Aerospace Technology Enterprise for a Systems Technology Project. It is consistent with NPD 7120.4, NPG 7120.5A, and ISO 9001. This plan is the controlling document that defines the top level technical and management structure of the CAS Project. It covers the time period of FY2000-2006.

The CAS Project described in this document accelerates the development of high-performance computing technologies to meet the needs of the US aerospace community. It also accelerates the distribution of these technologies to the American public. The technologies developed under this plan help maintain US technical and economic leadership in the international arena of high-performance computing.

1.2 Background

The main objective of the Federal HPCC R&D program is to extend US technological leadership in high-performance computing and computer communications. As this is accomplished, these technologies will be widely disseminated to accelerate the pace of innovation and improve national economic competitiveness, national security, education, health care, and the global environment. NASA's HPCC Program is a key contributor to the following current federal program component areas:

- High-End Computing and Computation
- Large-Scale Networking, including the Next Generation Internet
- Human Centered Systems
- Education, Training, and Human Resources

The NASA HPCC Program is a critical element of the Federal IT R&D effort. NASA's primary contribution to the Federal program is its leadership in the development of algorithms and software for high-end computing and communications systems which will increase system effectiveness and reliability, as well as support the deployment of high-performance, interoperable, and portable computational tools. As HPCC technologies are developed, NASA will use them to address aerospace transportation systems, Earth sciences, and space sciences research challenges. NASA's specific research challenges include improving the design and operation of advanced aerospace transportation systems, increasing scientists' abilities to model the Earth's climate and predict global environmental trends, furthering our understanding of our cosmic origins and destiny, and improving the capabilities of advanced spacecraft to explore the Earth and solar system. The HPCC Program supports research, development, and prototyping of technology and tools for education, with a focus on making NASA's data and knowledge accessible to America's students. These challenges require significant increases in computational power, network speed, and the system software required to make these resources effective in real-world science and engineering environments.

In support of these objectives, the NASA HPCC Program develops, demonstrates, and prototypes advanced technology concepts and methodologies, provides validated tools and techniques, and responds quickly to critical national issues. As technologies mature, the NASA HPCC Program facilitates the infusion of key technologies into NASA missions activities, and the national engineering, science and education communities, and makes these technologies available to the American public. The Program is conducted in cooperation with other US Government programs, the US industry, and the academic community.

The Program has been organized into five customer-focused Projects which strive to develop, demonstrate, and infuse into customer processes integrated systems of application, system software, and testbeds which, in total, meet the overall HPCC Program goal and each of the customer impact and technical objectives.

The CAS Project is one of the five projects within HPCCP. CAS addresses the high-end computing needs of the NASA Aerospace Technology Enterprise and the national aerospace community, including other government agencies, industry, and academia. The CAS goal is to enable improvements to NASA technologies and capabilities in aerospace transportation through the development and application of high-performance computing technologies, transferring these technologies to NASA and the broader aerospace community. This will provide the aerospace community with key tools necessary to reduce design cycle times and increase fidelity in order to improve the safety, efficiency, and capability of future aerospace vehicles and systems. The CAS Project works with other Aerospace Technology Enterprise programs and the national aerospace community to select high priority areas that have bottlenecks or limits that could be addressed through the application of high-end computing. These challenging, customer-focused applications guide efforts on advancing aerospace algorithms and applications, system software, and computing machinery. These advances are then combined to demonstrate significant improvements in overall system performance and capability.

1.3 Project Goals

The CAS Project addresses the high-end computing needs of the NASA Aerospace Technology Enterprise and the national aerospace community, including other government agencies, industry, and academia. The CAS goal is to:

Enable improvements to NASA technologies and capabilities in aerospace transportation through the development and application of high-performance computing technologies and the infusion of these technologies into the NASA and national aerospace community.

1.4 Overall Strategy and Approach

The CAS Project facilities the transfer of technology developed in NASA aerospace and information technology research efforts to routine use by operationally-oriented or product-oriented programs within the NASA Aerospace Technology Enterprise. This will provide the aerospace community with key tools necessary to increase simulation fidelity and reduce design cycle times in order to improve the capabilities, safety, efficiency, and operations of future aerospace vehicles and systems. This has the additional benefit of establishing within the aerospace community a viable market for vendors of high-performance computing hardware and software. CAS, because of this relationship with the general computer science community, provides input and direction for developing technology for aerospace application.

The CAS Project works with NASA Aerospace Technology Enterprise Programs and the national aerospace community to select high priority areas that have bottlenecks or limits that could be addressed through the application of high-end computing. These challenging, customer-focused applications guide efforts on advancing aerospace algorithms and applications, system software, and computing machinery. These advances are then combined to demonstrate significant improvements in overall system performance and capability.

1.5 Project Components

CAS is organized into and supports work in the following areas:

- Project Management
- Aerospace applications and algorithms, providing the customer focus
- Computing testbeds, providing the laboratory of research hardware
- Systems software that forms the interface between the testbed and the user
- Basic Research and Human Resources

In this way, the project brings together a collaborative team of developers so that the proper balance of activities can be orchestrated across the full spectrum of computational technology from applications to hardware.

In the long term, the technologies developed in CAS will enable much of the entire life cycle of a vehicle to be simulated. These technologies will be transferred to existing and emerging aerospace and information systems activities, specifically targeting those striving to meet NASA's aerospace technology goals. Through partnerships with the extended CAS community of government agencies, industry, and academia; additional bi-directional technology transfer will occur.

Through the Basic Research and Human Resources (BRHR) component of the project, CAS supports the development of trained computer science and computational aerospace science professionals for the future. In addition, CAS continually collaborates with the Learning Technologies Project (LT) to evaluate CAS technologies for broader application to the public interest. For example, simpler versions of applications (e.g., for aircraft or engine design) could be created in "education versions" as opposed to "engineering versions."

1.6 Scope of Project Plan

The CAS Project Plan provides an authoritative, top-level technical and management description of the project and is the controlling document for project content and organization. This plan is regularly updated to reflect project progress and strategic adjustments. The main purpose of this project plan is to establish:

- Project objectives and performance goals
- Project requirements
- The management organizations responsible for the project throughout its life cycle
- Project resources, schedules, and controls

This project plan is consistent with the normal procedures used by the Aerospace Technology Enterprise for Systems Technology Project. It is consistent with NPD 7120.4, NPG 7120.5A, and ISO 9001. This project plan covers the time period of FY2000-2006.

2. OBJECTIVES

Of primary importance to the CAS Project is contributing to meeting the goal of the HPCC Program in enabling the use of high-performance computing and communication technologies to improve the effectiveness of the HPCC Program's customers. The HPCCP customer impact objective is:

Infuse HPCCP technologies into mission critical stakeholder Enterprise/Office processes, document discernable improvements in the stakeholders' processes and, if possible, document discernable improvements in the final products as a result of the use of HPCCP technologies.

In contributing to this overall Program customer impact objective, each project has a particular focal point, and the focal point for CAS is the Aerospace Technology Enterprise. To meet the customer impact objective, it is necessary to achieve specific improvements in performance, interoperability, portability, reliability, resource management, and usability. These are shown in the sections below. They have been adapted from the HPCC Program Objectives.

2.1 CAS Customer Impact Objective

Performance goals

Demonstrate or document the use of HPCCP technologies to support the reduction in the design cycle time of at least ten NASA or NASA-sponsored design events, from at least five distinct NASA Programs, contributing directly to the Aerospace Technology Enterprise goals.

Demonstrate or document the use of HPCCP technologies to enable the analysis or simulation, as appropriate, of three distinct elements of the National Air Space contributing directly to the Aerospace Technology Enterprise goals.

Performance indicators

- Industry and NASA baseline metrics
- Availability of computational tools
- Infusion of HPCC Program technologies and applications into NASA communities

2.2 Computational Performance Objective

Dramatically increase the computer performance available for use in meeting NASA mission requirements.

Performance is defined as the rate at which a computer performs operations, a network transfers data, a storage system stores/retrieves data or an application and underlying computational system completes a task.

Performance goals

Demonstrate the effective use on NASA aerospace systems of computational systems delivering:

- 250 Gigaflops sustained on applications, ground based

Demonstrate the effective use on NASA aerospace systems of applications delivering:

- A complete vehicle analysis in one day
- A complete high-fidelity (3-D) propulsion system analysis in one day

Performance indicators

- Capability computing testbeds
- Development of low-cost platforms
- Performance analysis and monitoring tools
- Reduction of requirements through improved algorithms

2.3 Interoperability Objective

Dramatically increase the interoperability of application and system software operating on high-performance computing and communications systems available for use in meeting NASA mission requirements.

Interoperability is defined as the ability of software on multiple machines from multiple vendors to communicate.

Performance Goals

Demonstrate on NASA aerospace systems technologies that enable:

- Interoperation among at least ten distinct computational simulation, data analysis, or other tools spanning at least three aerospace disciplines
- Integration of a new computational simulation, data analysis, or other tool into an interdisciplinary framework in one day
- Integration of a new computing or storage system into a computational grid in one day

Performance Indicators

- Industry-standard software design and coding practices
- Configuration management and interface agreements

2.4 Portability Objective

Dramatically improve the portability of application software and data to new or reconfigured high-performance computing and communications systems available for use in meeting NASA mission requirements.

Portability is defined as the ease with which a piece of software (or file format) can be "ported", i.e. made to run on a new platform and/or compile with a new compiler.

Performance Goals

Demonstrate on NASA aerospace systems, technologies that enable:

- Successful execution of a computational simulation, data analysis, communication, or other tool on a new computer, network, or storage system, or combination of these resources within one week.
- Successful execution of a computational simulation, data analysis, communication, or other tool on a computer, network, or storage system, or combination of these resources within one day of a modification in the software or hardware configuration of these resources.

Performance Indicators

- Use of software engineering techniques
- Software reusability

2.5 Reliability Objective

Dramatically improve the reliability of user-requested events executing on high-performance computing and communications systems available for use in meeting NASA mission requirements.

Reliability is defined as the probability that a given computer-based event (e.g., computational operation, data transfer or storage) will complete successfully.

Performance Goals

Demonstrate on NASA aerospace systems applications the successful execution of 99% of the user requested computational events over a 24-hour time period on a distributed computational system including at least ten distinct resources, including at least one computer platform, one mass storage system, and one wide-area network.

Performance Indicators

- Reliability testing
- Development of application algorithms designed to allow enhanced reliability
- Distribution of system software to enable enhanced reliability

2.6 Computational Resources Management Objective

Dramatically improve the ability to manage heterogeneous and distributed high-performance computing, storage, and networking resources available for use in meeting NASA mission requirements.

Resource management is defined as the ability to allocate compute, network, and/or storage resources to allow the most appropriate execution of an event request.

Performance Goals

Demonstrate on NASA aerospace systems the ability to allocate compute, storage, and network resources to a requested computational event, including at least ten distinct resources, including at least one computer platform, one mass storage system, and one wide-area network.

Performance Indicators

- Fielding of applications capable of effectively exploiting distributed resources
- Distribution of software to enable simple and timely allocation of resources
- Identification of a computing, storage, and networking resource pool which can be allocated

2.7 Customer Usability Objective

Dramatically improve the usability of high-performance computing tools and techniques available for use in meeting NASA mission requirements.

Usability is characterized as the effectiveness, efficiency, and satisfaction with which users can achieve tasks in the user environment presented by a technology or integrated system of technologies. High usability means a system is easy to learn and remember; efficient, visually pleasing and easy to use; and quick to recover from errors.

Performance Goals

Demonstrate visual based assembly and successful execution of aerospace applications.

Performance Indicators

- Usability testing
- Identification of specific usability requirements
- Development of software modules or systems to enhance usability

3. CUSTOMER DEFINITION AND ADVOCACY

The primary customer of the CAS Project is the NASA Aerospace Technology Enterprise. This includes researchers in applied computational aerospace sciences, researchers in computer science, and engineers developing aeronautical and space transportation systems. The broader CAS customer base includes aerospace vehicle and engine manufacturers, the academic aerospace community, and the information technology industry that supplies commercial technology to the aerospace community.

The CAS Project is reestablishing a CAS Review and Planning Team (CAS R&PT) consisting of key individuals in the NASA and broader aerospace community including representatives from Aerospace Technology Enterprise programs, other government agencies, academia, and industry. The individuals on the CAS R&PT will be the primary points of contact between their respective organizations and the CAS Project. The CAS R&PT will represent the aerospace community and serve as liaisons between the CAS Project and the aerospace community.

4. PROJECT AUTHORITY

The overall authority for the CAS Project is established by the HPCC Program Plan, which in turn is established by NASA Headquarters Program Management Council (PMC). The HPCC Program Commitment Agreement (PCA) represents the Agency-level agreement for the implementation of the HPCC Program and its projects.

5. MANAGEMENT

5.1 Organization and Responsibilities

The NASA Office of Aerospace Technology, Office of Earth Science, Office of Space Science, and Office of Human Resources and Education are the stakeholders of the HPCC Program. Overall program objectives, requirements, and metrics are established by the NASA HPCC Executive Committee, composed of Associate Administrators of all of the NASA Agency Office stakeholders and chaired by the Associate Administrator of the Office of Aerospace Technology. The NASA Office of Aerospace Technology is the NASA Headquarters focal point for coordinating the Program's Headquarters-level approvals, reviews, and customer advocacy. NASA Ames Research Center is responsible for the overall direction, control, and oversight of the HPCC Program. Under the direction of the Ames Center Director, the HPCC Program Office located at Ames is responsible for the overall management and execution of the Program, including the maintenance of program-level plans, coordination of program-level reviews, and the overall coordination of work across the Projects. Other program management responsibilities are described in the HPCC Program Plan.

The CAS Project is one of five projects within the NASA HPCC Program and is supported by three participating NASA centers: Ames, Glenn, and Langley. Ames has been designated the lead center for the CAS Project. The CAS Project Manager is appointed by the HPCC Program Manager and reports to the HPCC Program Manager.

The responsibilities of the CAS Project Manager include:

- Overall management of the assigned multi-center project, including cost, schedule, and technical performance
- Preparing and maintaining the project plan, specifications, schedules, and budgets
- Forming the project team and executing the project plan
- Establishing support agreements
- Acquiring and utilizing participating contractors
- Performing financial and acquisition management, risk management, performance management, and safety and mission assurance
- Reporting project performance and status, including contracts, to the HPCC Program Office and as otherwise required
- Submitting project reports and preparing and presenting project reviews and technical advocacy materials
- Supporting the HPCC Program management and integration
- Maintaining a current Project-level website linked to the HPCC Program website
- Complying with applicable Federal law, regulations, Executive orders, and Agency Directives

Participating NASA Centers assign an Associate Project Manager as a center point of contact and to oversee CAS Project activities at the center. The responsibilities of the Associate Project Managers include:

- Coordinating and managing Project Work Breakdown Structure (WBS) elements at their centers

- Tracking and reporting the implementation of their center's research activities in support of the Project
- Preparing, submitting, and presenting reports, reviews, and briefings on project implementation status to the Project Manager and to the senior managers at their respective centers

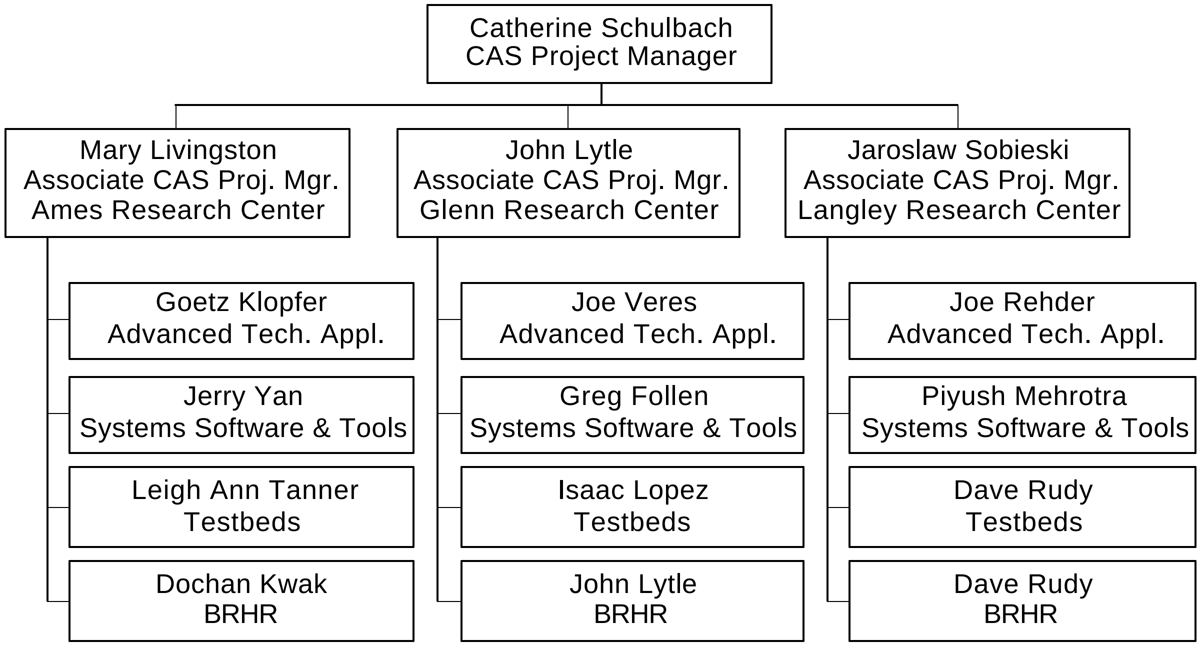
Each center has Task Managers that coordinate the performance of that center's work in each of the WBS elements. A Task Manager oversees one of the following WBS element efforts at one of the participating Centers:

- Advanced Technology Applications
- Computing Testbeds
- Systems Software and Tools
- Basic Research and Human Resources

The responsibilities of the Task Manager include:

- Supporting the CAS Project Manager and Associate CAS Project Managers
- Representing a center's WBS element to the CAS Project Manager and Associate Project Managers
- Leading the definition of resources, schedules, deliverables, and commitments in a center's WBS element
- Monitoring and coordinating technical efforts in a center's WBS area
- Managing center's WBS budget
- Reporting technical performance and status to the CAS Project Manager and Associate Project Managers, other Project personnel, and line managers

The project organization is shown below:



5.2 Special Boards and Committees

A key aspect of the CAS Project is early and continuous interaction with and involvement of the national aerospace and computing communities. The CAS Project actively fosters this relationship through workshops, periodic in-depth reviews, and planning and review activities as appropriate. These workshops and review activities are designed to elicit direct, unfettered feedback from the nation's experts regarding the goals, objectives, priorities and structuring of the research planned under the CAS Project.

The CAS Project is reestablishing a CAS R&PT consisting of key individuals in the NASA and national aerospace community including representatives from Aerospace Technology Enterprise programs, other government agencies, academia, and industry. The individuals on the CAS R&PT will be the primary points of contact between their respective organizations and the CAS Project. The members of the CAS R&PT will represent the aerospace community and serve as liaisons between the CAS Project and the aerospace community. The CAS R&PT will meet annually in conjunction with the CAS Project budgeting and planning process and will be consulted and informed regularly.

5.3 Management Support Systems

Ames is the lead center for the HPCC Program and the CAS Project. Ames is also the lead center for the Information Technology (IT) Base Research and Technology Program, and the Consolidated Supercomputing Management Office (CoSMO). The CAS Project works closely with the IT Program and with CoSMO. This allows the project to leverage the research results of the IT Base Research and Technology Program as well as to transition its own results into operational use by CoSMO.

The HPCC Program Office provides important interfaces to the NASA Enterprises and Headquarters Offices through the HPCC Executive Committee and HPCC Executive Committee

Working Group. This provides CAS with information on NASA and Enterprise priorities and feedback on project accomplishments.

6. TECHNICAL SUMMARY

6.1 Project Requirements

The CAS Project derives its requirements from the needs of the Aerospace Technology Enterprise and the national aerospace community. These needs determine the advanced technology application activities to be addressed, and the advanced technology applications activities in turn drive the work that needs to be done in the systems software and computing testbeds areas. Planned updates to the underlying computing testbeds (hardware and software) and changes in NASA priorities require periodic updating and revising of CAS Project efforts.

The CAS customer-focused, *Advanced Technology Applications (ATA's)* are aerospace problems that are selected because of their importance to NASA's Aerospace Technology Enterprise, their ability to drive high-performance end-to-end computational technology development, and their ability to cover the spectrum of the types of problems expected to be encountered by the aerospace community in the next 3-10 years. The ATA's are selected through partnership with the Aerospace Technology Enterprise; and ATA research focuses on areas critical to the entire lifecycle of aerospace vehicles, from concept through operation, providing tools necessary to increase simulation fidelity and reduce design cycle times in order to improve the capabilities, safety, efficiency, and operations of future aerospace vehicles and systems.

ATA efforts include improving and streamlining the analysis process (from set-up to post-processing), coupling the analyses of multiple disciplines and components, and integrating models and analyses for comprehensive analysis, design, and optimization. This will be done in ways to enable operation on HPCCP testbeds and to facilitate eventual transfer to other organizations through attention to performance, portability, interoperability, reliability, resource management and usability.

To exploit the potential for highly concurrent processing using large numbers of processors, whether in one machine or in many, networked machines, CAS develops new tools for analysis and optimization that reflect the underlying physics and yet are tailored to the highly concurrent architectures. Algorithm innovations will be required to make best use of these highly concurrent architectures. For example, algorithms are needed that operate effectively on computing systems with long and/or non-homogeneous latencies between computing nodes. Algorithms must not only be latency-tolerant but must be latency-adaptive. Algorithmic innovations are also required to address other bottlenecks that currently inhibit the effective and efficient use of new architectures. These other bottlenecks include diminishing returns of increasing the number of processors and the difficulty in balancing the workload.

The CAS *System Software* effort takes system-level services developed to enable performance, portability, interoperability, reliability, resource management and usability; and provides to the user the tools to enable improved and predictable turnaround and throughput. For example, tools must be provided to enable applications to be easily moved between systems with little or no human intervention. Tools must also be provided to create, maintain, and use modular application components that can inter-operate; and users' effort must be minimized through easy-to-use tools and a reliable system.

The CAS *Computational Testbed* effort is focused on providing a continuously evolving research testbed for the development of ATA's. In Phase I of the HPCC Program and the CAS Project, CPU speed and memory were the bottlenecks, and so CAS supported the acquisition and use of a series of high-performance parallel computing systems. CAS also supported the development and evaluation of cost-effective workstation clusters.

This focus on individual systems was important when the ATA focus was largely on improving the speed of computations for individual disciplines and/or components. While still important, aerospace problem solving now encompasses much more. It is likely to involve geographically distributed teams, running 24 hours around the clock and requiring computing and experimental tools and data archives to simulate multi-disciplinary interactions between components. Ability to make use of all available resources and corporate knowledge and to have access to reusable components and tools play a vital role in reducing cost and risk as well.

In this environment, single systems (even massively parallel ones) are insufficient and/or cost, prohibitive. Yet computing resources are everywhere. At the same time, speed and predictability of turn around time are crucial in making use of distributed heterogeneous systems. A seamless interface to a reliable and predictable system is needed to limit the labor-intensive tasks of porting applications from system to system.

Fortunately, new nation-wide efforts to develop computational grids provide promising technologies for improving turn-around time and throughput by providing the basis and infrastructure to retain/improve performance while enabling portability, interoperability, reliability, resource management, and usability. The key is to hide from the user the detailed components and architecture of the grid by providing services that remain unchanged regardless of changes to the underlying components. An example is providing system-level services that improve scheduling capability through modeling, monitoring, prediction, load balancing, resource reservation and quality of service guarantees.

Just as CAS works with the aerospace community to identify problems and work on bottlenecks in the application area, CAS also works with the information systems community and the HPCCP NASA Research and Education Network (NREN) Project to transfer computing and communications technologies from the research to the operational environment. One aspect of this is for CAS to provide access to hardware and software testbeds to the wider aerospace community (not just to ATA-funded researchers) so that other scientists and engineers can have access to the new technology and so that they can provide a wider range of challenges to the testbed systems.

The results of the efforts in the four CAS work breakdown structure areas (advanced technology applications, systems software, and computational testbeds) are brought together in demonstrations of new and improved capabilities such as:

- Multi-disciplinary, three-dimensional simulation of a complete propulsion system in one day.
- High-fidelity, full-vehicle simulation of commercial aircraft or advanced concept vehicle in one day.
- Multi-disciplinary analysis of a new space transportation vehicle for flight characteristics in one day, and optimization in one week.
- Simulation of the nation air transportation system for safety and/or capacity in one day.

6.2 Systems

Systems requirements are determined at the highest level by a combination of milestone success criteria and application requirements. Further refinement of the requirements of the individual systems and activities are determined through detailed planning discussions with managers and researchers in other NASA Aerospace Technology programs, discussions and visits with industry representatives, review of relevant documents, internal planning workshops, and other activities. Review of survey results and feedback obtained from the HPCC Program Office and line managers also contribute to establishing detailed system requirements.

6.3 System Operations Concept

CAS advanced technology applications are chosen to guide the development of computer system hardware and software. Applications software developed under the CAS Project is developed to demonstrate new capabilities and is generally not taken beyond Technology Readiness Level (TRL) 6. However, through demonstration efforts, CAS addresses many of the obstacles to moving technology beyond TRL 6, and thus facilitates technology exchange between the research and operations efforts within NASA and the aerospace community. To take technologies beyond TRL 6, partnerships are established with other organizations. Such partnerships may be with other NASA organizations or with commercial organizations and may take on many forms depending on the product.

6.4 Systems Constraints

The CAS Project is a computer research project. Its primary products are software and information about how to use information systems technology. The CAS Project does not deal with flight systems or real time systems. CAS systems are ground based systems used for research activities, and there are no special systems constraints for hardware or software.

6.5 Ground Systems and Support

There are no special facilities for ground systems and/or support.

6.6 Facilities

No new facilities are required.

6.7 Logistics

There are no special requirements for logistics.

6.8 Mission Results Analysis and Reporting

Results are reported through normal reporting channels.

7. SCHEDULES

The PCA and Program milestones for the HPCC Program are shown below in Figure 7-1. CAS contributes to some but not all of these. The Program milestones and the output metrics to which the CAS Project contributes are shown in Table 7-1. CAS Project milestones are shown in Table

7-2 along with the PCA and Program milestones they support. Figure 7-1 and Tables 7-1 and 7-2 are intended to be consistent with HPCC Program Plan.

Figure 7-1: PCA and Program Milestones.

PCA and Program Milestones	Due Date
PCA-1 Develop component technologies for performance	**9/30/01**
1.1 Establish high-performance testbed for application performance (CAS/ESS/NREN)	10/3/00
1.2 Establish 1st generation scalable embedded computing testbed (REE)	6/30/01
1.3 Develop and apply technologies to measure and enhance performance on high-performance testbeds (CAS/ESS/NREN)	9/30/01
PCA-2 Develop component technologies for reliabili and resources management	**6/30/03**
2.1 Develop real-time reliability for spaceborne computing (REE)	3/29/02
2.2 Develop embedded tools and services for autonomous resource estimation/request of local and distributed ground-based systems (CAS/ESS/NREN)	12/31/02
2.3 Develop tools for reliability of ground-based computing systems (CAS)	6/30/03
PCA-3 Develop component technologies for interoperability and portability	**9/30/03**
3.1 Tools and techniques for interoperable and portable applications in aerospace, Earth science and space science communities (CAS/ESS)	3/29/02
3.2 Interoperable and portable networking technologies (NREN)	9/30/02
3.3 Interoperable and portable systems, services and environments (CAS/ESS)	9/30/03
PCA-4 Develop component technologies for usabilit	**9/30/04**
4.1 Prototype/establish advanced technologies that serve as a catalyst for learning environment use of engineering and scientific data (LT)	9/30/00
4.2 Production-ready breakthrough technologies that serve as a catalyst for learning environment use of engineering and scientific data (LT)	9/30/02
4.3 Develop tools to improve usability of aerospace simulation capabilities (CAS)	3/31/04
4.4 Develop prototype of revolutionary multisensory multimedia technology for education (LT)	9/30/04
PCA-5 Demonstrate integrated HPCC technologies	**9/30/02**
5.1 Demonstrate embedded applications on 1st generation spaceborne computing testbed (REE)	9/29/00
5.2 Demonstrate integrated learning technology products in relevant educational environments (LT)	9/28/01
5.3 Demonstrate improvement in time-to-solution for aerospace applications (CAS)	12/31/01
5.4 Demonstrate embedded applications using fault-tolerant techniques (REE)	6/28/02
5.5 Demonstrate significant improvements in Earth and space science application codes (ESS)	9/30/02
5.6 Demonstrate end-to-end networking capabilities on NASA mission-oriented applications (NREN)	9/30/02
PCA-6 Demonstrate significant engineering, scientifi and educational impacts from integrated HPCC technologies.	**9/30/05**
6.1 Establish impact on Earth and space sciences through the demonstration of a production-ready high-performance Earth and space science computational simulations validated by NASA Enterprise observational mission data (ESS/NREN)	9/30/03
6.2 Establish impact on space mission through the demonstration of a flight-ready integrated system software, testbed, and application system (REE)	6/30/04
6.3 Establish impact on aerospace design and operations through the demonstration of integrated systems of applications, tools, services and resources which enable the high-performance execution of interoperable aerospace applications across distributed heterogeneous testbeds (CAS/NREN)	9/30/05
6.4 Establish impact on NASA's education mission through the demonstration of prototype revolutionary multisensory multimedia systems for education (LT/NREN)	9/30/05
PCA-7 Establish sustainable and wide-spread custon use of HPCC Program technologies	**9/29/06**
7.1 Establish sustained price-performance improvements for Earth and space science applications (ESS)	9/30/04
7.2 Established sustained utilization of commercial computing technologies for spaceborne applications (REE)	9/30/05
7.3 Enable sustained use of LT technologies by educational community (LT)	9/30/05
7.4 Establish sustained use of CAS tools and techniques towards meeting Aero-Space Technology Enterprise goals and objectives (CAS)	9/29/06
7.5 Transfer NREN technologies to NASA's operational WAN (NREN)	9/29/06

Table 7-1.: Program Milestones and Output Metrics to which CAS Project Contributes.

Milestones	Due Date	Output Metrics
PCA-1 Develop component technologies for performance	**09/01**	
1.1 Establish high-performance testbed for application performance	09/00	Integrated hardware and software to provide a computing and communications testbed for HPCC applications capable of 250 GFLOPS (benchmarks) and 3 locations with Gigabit WAN capability.
1.3 Develop and apply technologies to measure and enhance performance on high-performance testbeds	09/01	Software tools to reduce parallelization time from months to one week while maintaining 50% application performance compared with manual parallelization. Tools to benchmark testbed performance in computing capability, database manipulation, and scheduling to evaluate alternate scheduling strategies and choose optimal approaches to reduce variability and improve predictability of turnaround time. 3 relevant application codes parallelized; 3 data analysis codes parallelized; documented evaluation of parallelization tools.
PCA-2 Develop component technologies for reliability and resources management	**06/03**	
2.2 Develop embedded tools and services for autonomous resource estimation/request of local and distributed ground based systems	12/02	Tools for broadcasting local system status for utilization on distributed systems. 3 applications with tools for automated submission and management of multiple jobs; 3 applications with tools for utilization of new or modified resources on a distributed computing system within 1 day. Tools for job execution management on distributed systems; integration of new computing or storage node into distributed computing system within one day.
2.3 Develop tools for reliability of ground-based computing systems	06/03	CAS: Application tools to detect, classify and adapt to faults on distributed computing nodes and networks; 99% availability on distributed computing systems (10 distinct resources including one each of computing node, mass storage and wide area network).

PCA-3 Develop component technologies for interoperability and portability	**09/03**	
3.1 Tools and techniques for interoperable and portable applications in aerospace, Earth Science and space science communities	03/02	Distributed debugging capability on 6 distinct platforms; adapt codes for interoperability within 1 week.
3.3 Interoperable and portable systems, services and environments	09/03	Interoperability of 3 tools pre-processing CAD geometry data for application input; interoperability of 10 tools spanning 3 aerospace disciplines and including high-fidelity analysis; integration of new tool into interoperability framework within one day.
PCA-4 Develop component technologies for usability	**09/04**	
4.3 Develop tools to improve usability of aerospace simulation capabilities	03/04	Visual-based assembly capability applied to 3 aerospace applications to speed the problem set-up, reduce learning time, and reduce set-up errors.
PCA-5 Demonstrate integrated HPCC technologies	**09/02**	
5.3 Demonstrate improvement in time-to-solution for aerospace applications	12/01	Improvement in aerospace applications: Complete combustor and compressor simulation in 3 hours each; high-fidelity space transportation vehicle analysis in 1 week and optimization enabled; S&C database generation for aerospace vehicles within 1 week; demonstration of improvements in 4 NASA-sponsored design events.
PCA-6 Demonstrate significant engineering, scientific, and educational impacts from integrated HPCC technologies	**09/05**	
6.3 Establish impact on aerospace design and operations through the demonstration of integrated systems of applications, tools, services and resources which enable the high-performance execution of interoperable aerospace applications across distributed heterogeneous testbeds	09/05	Utilize distributed heterogeneous computing system (10 components) for: 3D steady-state multidisciplinary propulsion system analysis in 1 day; high-fidelity full-vehicle simulation of aircraft in 1 day; high-fidelity space transportation vehicle analysis in 1 day and optimization in 1 week. Document improvements in 6 NASA-sponsored design events and impact to 3 elements of the national airspace system.

PCA-7 Establish sustainable and wide-spread customer use of HPCC Program technologies	**09/06**	
7.4 Establish sustained use of CAS tools and techniques towards meeting Aerospace Technology Enterprise goals and objectives	09/06	Surveys demonstrating infusion of production-ready applications and system software tools into NASA Aerospace Technology programs, aerospace engineering industry and high-performance computing communities.

Table 7-2: CAS Project Milestones.

Identifier	Milestone	Due Date
PCA1	**Develop component technologies for performance**	**9/30/01**
HPCCP1.1	Establish high-performance testbed for application performance	9/30/00
C1.1.1	512-processor Origin 2000 available to CAS community	5/1/00
C1.1.2	512-processor Origin 2000 integrated into distributed testbed	7/1/00
C1.1.3	Demonstration of 250 GFLOPS benchmark on testbed	9/1/00
HPCCP1.3	Develop and apply technologies to measure and enhance performance on high-performance testbeds	9/30/01
C1.3.1	Apply parallelization tools to benchmarks and document performance	6/30/00
C1.3.2	Apply parallelization tools to flow solvers and data analysis codes and document performance	12/31/00
C1.3.3	Document that parallelization tools can parallelize application in one week while maintaining 50% performance compared to manual parallelization	6/30/01
C1.3.4	Develop high performance extensions for OpenMP and evaluate using CAS codes	9/30/01
C1.3.5	Develop HPF, OpenMP, and Java implementations of NAS Parallel Benchmarks (NPB)	9/30/01
C1.3.6	Develop database benchmark to evaluate database manipulation capabilities	9/30/01
C1.3.7	Develop execution benchmark for testing alternate scheduling strategies	9/30/01
C1.3.8	Develop initial parallel versions of PEGSUS, CART3D, CIR, and INS3D; document performance; and compare to serial versions	9/30/01
C1.3.9	Develop parallel version of unsteady turbomachinery code MSTURBO, document performance, and compare to serial version	9/30/01
C1.3.10	Develop initial parallel versions of data reduction codes, document performance, and compare to serial version	9/30/01
C1.3.11	Investigate innovative algorithms for high performance	9/30/01
C1.3.12	Investigate highly-parallel, distributed algorithms for aerospace propulsion applications	9/30/01
C1.3.13	Develop algorithmic enhancements for selected parallel applications to improve execution time 25%	9/30/01
C1.3.14	Demonstrate distribution of analysis and optimization on many concurrently operating processors by replication of existing codes (coarse-grain parallelism) for subset of RLV problem	9/30/01
PCA2	**Develop component technologies for reliability and resources management**	**12/31/02**
HPCCP2.2	Develop embedded tools and services for autonomous resource estimation/request of local and distributed ground based systems	12/31/02
C2.2.1	Demonstrate ability to incorporate and utilize a new computing or storage node into distributed computing system	3/31/01

C2.2.2	Provide information on queuing, tracking, and monitoring jobs in distributed systems that can be accessed by user applications	9/30/01
C2.2.3	Provide information on status of components of distributed system resources that can be accessed by user applications	9/30/01
C2.2.4	Develop Jini-based resource management and scheduling system for MDO applications	9/30/01
C2.2.5	Develop tool for automated job submission	3/31/02
C2.2.6	Demo automated job submission tool on 3 applications	12/31/02
C2.2.7	Demo ability of 3 applications to incorporate and utilize new or modified resources	12/31/02
HPCCP2.3	Develop tools for reliability of ground based computing systems	6/30/03
C2.3.1	Develop application tools to detect, classify and adapt to faults on distributed computing nodes and networks	6/30/03
C2.3.2	Demonstrate 99% availability on distributed computing systems	6/30/03
PCA3	**Develop component technologies for interoperability and portability**	**9/30/03**
HPCCP3.1	Tools and techniques for interoperable and portable applications in aerospace, Earth science and space science communities	3/31/02
C3.1.1	Evaluate methods of providing user interface to distributed systems	6/30/01
C3.1.2	Demonstrate that p2d2 can be used to debug program distributed across multiple distinct platforms	9/30/01
C3.1.3	Develop and demonstrate tool to semi-automatically derive application interfaces for CORBA environment	9/30/01
C3.1.4	Develop tools for wrapping and executing legacy codes using CORBA	12/31/01
C3.1.5	Evaluate approaches to deploying security services in distributed systems	9/30/02
HPCCP3.3	Interoperable and portable systems, services and environments	9/30/03
C3.3.1	Demonstrate NPSS capability to deploy zoomed parameter study between engine and 1D high pressure compressor using CORBA	9/30/01
C3.3.2	Demonstrate NPSS capability to deploy zoomed parameter study between engine and 1D high pressure compressor using CORBA, with CAPRI CAD interface	9/30/02
C3.3.3	Enhance PEGSUS to be capable of producing flow solver ready overset grid systems and running coupled w/flow solver to produce grids for moving unsteady problems	9/30/03
C3.3.4	Demonstrate capability to integrate new tool into NPSS	9/30/03
C3.3.5	Develop high performance language extensions and evaluate using CAS applications	9/30/03
C3.3.6	Extend resource management and scheduling system to include modules for security, monitoring and steering	9/30/03

PCA4	**Develop component technologies for usability**	**9/30/04**
HPCCP4.3	Develop tools to improve usability of aerospace simulation capabilities	3/31/04
C4.3.1	Demonstrate NPSS V 1.0 with Visual Based Syntax assembly of complete engine (zoomed analysis)	9/30/02
C4.3.2	Demonstrate CORBA interface for executing applications in distributed environment with security	12/31/03
C4.3.3	Demonstrate adaptive coupling for object-based multidisciplinary application	9/30/04
C4.3.4	Develop tool with automated gridding and pre-processing capabilities and ability to perform grid-resolution error assessment and grid refinement.	9/30/04
C4.3.5	Assess potential of advanced computing/optimization methods to provide order-of-magnitude improvements in speed and/or capability	9/30/04
PCA5	**Demonstrate integrated HPCC technologies**	**9/30/02**
HPCCP5.3	Demonstrate improvement in time-to-solution for aerospace applications	12/31/01
C5.3.1	Demonstrate ability to couple tools for multi-disciplinary high-fidelity analysis of RSTS in descent	9/30/01
C5.3.2	Perform external and internal high-fidelity flow computations for RSTS in ascent	9/30/01
C5.3.3	Generate initial stability and controls database for aerospace vehicle	9/30/01
C5.3.4	Perform complete high-fidelity combustor simulation	9/30/01
C5.3.5	Perform complete high-fidelity compressor simulation	9/30/01
C5.3.6	Perform 3-D steady-state, aerodynamic simulation of aircraft engine	9/30/01
C5.3.7	Apply MDO to RLV conceptual design	9/30/02
PCA6	**Demonstrate significant engineering, scientific, and educational impacts from integrated HPCC technologies**	**9/30/05**
HPCCP6.3	Establish impact on aerospace design and operations through the demonstration of integrated systems of applications, tools, services and resources which enable the high-performance execution of interoperable aerospace applications across distributed heterogeneous testbeds	9/30/05
C6.3.1	Identify and integrate into CAS plans new CAS tasks to support National Air Space needs	9/30/00
C6.3.2	Perform high-fidelity aerodynamic analysis of RLV propulsion system	9/30/02
C6.3.3	Perform high-fidelity multi-disciplinary analysis of RLV propulsion system	9/30/03
C6.3.4	Perform time accurate computation of powered-lift vehicle in landing and/or takeoff maneuver	6/30/04

C6.3.5	Evaluate Computational Infrared Radiation (CIR) method for validating complex time-accurate aerodynamic flowfield predictions and reducing analysis time	6/30/04
C6.3.6	Perform combined internal/external steady simulation of RSTS in ascent with RBCC in air-breathing mode (include. Unsteady turbopump)	6/30/04
C6.3.7	Create optimized multidisciplinary designs of RSTS concept in descent	6/30/04
C6.3.8	Apply MDO to RLV preliminary design	6/30/04
C6.3.9	Perform high-fidelity steady-state multidisciplinary analysis of aircraft propulsion system	3/30/05
C6.3.10	Demonstrate integrated resource management and scheduling environment for RLV design cycle	9/30/05
C6.3.11	Apply MDO in multicenter application	9/30/05
PCA7	**Establish sustainable and wide-spread customer use of HPCC Program technologies**	**9/30/06**
HPCCP7.4	Establish sustained use of CAS tools and techniques towards meeting Aerospace Technology Enterprise pillars and goals	9/30/05
C7.4.1	Survey NASA aerospace and high performance computing communities and partners to determine infusion of CAS technology	9/1/00
C7.4.2	Demonstrate 5% improvement over previous year in level of infusion of CAS technology into Aerospace Technology Enterprise	Annual
C7.4.3	Support graduate and post-doctoral high-performance computing research	Annual

Work towards milestones is performed within one or more of the CAS Project work breakdown structure elements. The mapping of work on milestones to work breakdown structure elements is shown in figure 7-2. Elements of the CAS work breakdown structure are shown below along with their associated abbreviations:

- Project Management (Proj. Mgt.)
- Advanced technology applications (ATA)
- Computing testbeds (CT)
- Systems software and tools (SSW)
- Basic Research and Human Resources (BRHR)

Those milestones shown in red (C1.3.1, C1.3.10, C1.3.12, C1.3.13, C3.1.3, and C3.1.5) have work performed under two different work breakdown structure elements.

Figure 7-2. Mapping between milestones and work breakdown structure elements.

	PCA1	PCA2	PCA3	PCA4	PCA5	PCA6	PCA7
ATA	C1.3.6 C1.3.7 C1.3.8 C1.3.9 C1.3.10 C1.3.12 C1.3.13 C1.3.14		C3.3.3	C4.3.4	C5.3.1-C5.3.7	C6.3.2-C6.3.9 C6.3.11	
CT	C1.1.1 C1.1.2 C1.2.3	C2.2.1 C2.2.2 C2.2.3 C2.3.2	C3.1.5				
SSW	C1.3.1 C1.3.2 C1.3.3 C1.3.4 C1.3.5 C1.3.10	C2.2.4 C2.2.5 C2.2.6 C2.2.7 C2.3.1	C3.1.1-C3.1.5 C3.3.1-C3.3.2 C3.3.4-C3.3.6	C4.3.1 C4.3.2 C4.3.3		C6.3.10	
BRHR	C1.3.1 C1.3.11 C1.3.12 C1.3.13		C3.1.3	C4.3.5			C7.4.3
Proj. Mgt.						C6.3.1	C7.4.1 C7.4.2

Milestones in red appear in more than one WBS element.

8. RESOURCES

Funding and workforce budgets have been coordinated among the various NASA centers participating in the CAS Project. The following two sections present details in these two areas.

8.1 Funding Requirements

The CAS budget profiles for FY2000-2006 are shown in Table 8-1, by Center and by project work breakdown structure element. FY2006 is assumed to be the final year of the project.

Table 8-1: CAS Project budget by Center and by work breakdown structure element for FY2000-FY2006 (in $1000s).

CAS Budget	FY00	FY01	FY02	FY03	FY04	FY05	FY06	Totals
Ames Research Center	**9,918**	**11,707**	**12,657**	**13,190**	**14,700**	**12,700**	**6,600**	**81,472**
Applications	2,455	2,669	2,527	2,500	2,499	2,588	1,346	16,583
Computing Testbeds	2,699	3,737	3,411	3,917	5,607	3,408	1,773	24,551
Systems Software	3,125	3,565	4,887	4,835	4,706	4,874	2,535	28,527
BRHR	568	734	821	813	792	820	427	4,976
Project Management	1,071	1,001	1,011	1,125	1,097	1,010	520	6,835
Langley Research Cntr.	**4,180**	**4,275**	**4,258**	**4,812**	**4,200**	**4,200**	**2,200**	**28,125**
Applications	2,318	2,349	2,517	2,821	2,533	2,533	1,325	16,397
Computing Testbeds	300	297	300	294	241	241	132	1,806
Systems Software	721	773	719	823	724	724	378	4,861
BRHR	480	535	480	529	482	482	251	3,240
Project Management	360	320	242	346	220	220	114	1,821
Glenn Research Center	**5,668**	**5,268**	**5,485**	**6,198**	**5,400**	**5,400**	**2,700**	**36,119**
Applications	1,677	1,355	1,657	2,266	1,660	1,753	876	11,243
Computing Testbeds	222	224	222	222	223	226	113	1,451
Systems Software	3,037	2,839	2,854	2,979	2,764	2,729	1,365	18,566
BRHR	140	141	140	140	140	142	71	914
Project Management	592	709	612	591	613	550	275	3,944
CAS Totals	**19,766**	**21,250**	**22,400**	**24,200**	**24,300**	**22,300**	**11,500**	**145,716**

8.2 Institutional Requirements

The numbers of civil servants allocated by the NASA Centers to the CAS Project are shown in Table 8-2, by year, by Center, and by project work breakdown structure element. All entries are in full time equivalent (FTE) workyears.

Table 8-2: CAS Project civil servant staffing by Center and project work breakdown structure element for FY2000-2006 (in FTE workyears).

Civil Servant Workforce	FY00	FY01	FY02	FY03	FY04	FY05	FY06	Totals
Ames Research Center	**24.0**	**25.0**	**25.0**	**25.0**	**25.0**	**25.0**	**12.5**	**161.5**
Applications	15.5	16.5	16.5	16.5	16.5	16.5	8.3	106.3
Computing Testbeds	2.0	2.0	2.0	2.0	2.0	2.0	1.0	13.0
Systems Software	4.0	4.0	4.0	4.0	4.0	4.0	2.0	26.0
BRHR	1.0	1.0	1.0	1.0	1.0	1.0	0.5	6.5
Project Management	1.5	1.5	1.5	1.5	1.5	1.5	0.8	9.8
Langley Research Cntr.	**17.0**	**13.0**	**14.0**	**16.0**	**16.0**	**16.0**	**8.0**	**100.0**
Applications	11.0	8.5	8.5	10.5	10.5	10.5	5.3	64.8
Computing Testbeds	0.5	0.5	0.5	0.5	0.5	0.5	0.3	3.3
Systems Software	2.0	1.0	2.0	2.0	2.0	2.0	1.0	12.0
BRHR	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Project Management	3.0	3.0	3.0	3.0	3.0	3.0	1.5	19.5
Glenn Research Center	**51.0**	**54.0**	**54.0**	**54.0**	**54.0**	**54.0**	**27.0**	**348.0**
Applications	16.5	16.5	16.5	16.5	16.5	16.5	8.3	107.3
Computing Testbeds	3.5	3.5	3.5	3.5	3.5	3.5	1.8	22.8
Systems Software	28.0	31.0	31.0	31.0	31.0	31.0	15.5	198.5
BRHR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Project Management	3.0	3.0	3.0	3.0	3.0	3.0	1.5	19.5
CAS Totals	**92.0**	**92.0**	**93.0**	**95.0**	**95.0**	**95.0**	**47.5**	**609.5**

9. CONTROLS

9.1 Project Changes

The CAS Project Plan is the controlling document for the CAS Project. The CAS Project Manager has full authority to manage the project within the objectives, technical scope, schedule, and budgets established in the approved project plan. Changes to the approved project plan that do not affect the Program Plan or Program Commitment Agreement (PCA) require the approval of the HPCC Program Manager and Lead Center Director. Other, more extensive changes require the approvals specified in the HPCC Program Plan.

A formal process is used for managing project changes including requesting changes, acquiring the required level of approval, and tracking and documenting the changes. The CAS Project Office maintains the project change log.

9.2 Sensitive Technology

NASA center managers, working with industry and NASA HPCC researchers, are responsible for identifying sensitive technologies. These technologies are handled in such a way that their dissemination to foreign persons, companies, laboratories, and universities is restricted.

Sensitive information that is generated under formal cooperative research agreements between NASA and non-Federal parties is protected by the amended (October 1992) NASA Space Act of 1958. Data produced under such an arrangement will be protected from Freedom of Information Act requests for a period of 5 years after the date of dissemination.

Negotiated License Agreements are used to restrict access to privately developed technology performed under the auspices of the NASA HPCC Program. These agreements provide NASA with limited rights to use proprietary data or designs in NASA in-house or cooperative research projects. These agreements specify limits on the distribution and use of the proprietary data by NASA and NASA-licensed entities.

Some software and information developed solely within the NASA HPCC Program may be subject to protection under the Export Administration Regulations or the International Traffic in Arms Regulations, which are export controls established by law. The participants in the HPCC Program will follow applicable export control laws. These regulations establish lists or categories of technical data and/or products that may not be exported without an approved export license. (Note that the definition of “exported” includes “disclosed” and “discussed” as well as published.)

10. IMPLEMENTATION APPROACH

10.1 Implementation Approach

The CAS Project is planned, funded, managed, and executed in close cooperation with the Aerospace Technology Enterprise, the HPCC Program, other HPCC Projects, Federal agencies and laboratories, private industry, and academia to ensure that the fruits of this research project are brought into the NASA, commercial, and educational communities as rapidly as possible. CAS brings together a collaborative team consisting of testbed designers, systems software developers, and government and private sector aerospace methods/applications developers so that the proper balance can be orchestrated across the full spectrum of computational technology from hardware to applications. The CAS Project is coordinated with other NASA Aerospace Technology Enterprise base and focused program activities and with other Information Technology program activities. The project provides interim results of value to the aerospace community by developing, in close cooperation with NASA programs and the national aerospace community, near-term, intermediate, and long-term milestones that at each stage provide "end-user" benefits.

Work on the CAS Project is performed at Ames, Glenn, and Langley Research Centers by civil servants and contractors. Some work is also performed at off-site by contractors. Other work is performed at universities under grants, cooperative agreements, and, sometimes, contracts.

10.2 Project Summary WBS

The CAS Project work breakdown structure consists of the following elements: (1) advanced technology applications that provide the focus, (2) computational testbeds that provide the platforms for the advanced technology applications, (3) systems software that forms the interface between the user and the hardware, (4) Basic Research and Human Resources (BRHR) to support the development of trained computer science and computational aerospace science professionals for the future, and (5) project management to manage the other work breakdown structure elements of the project.

11.ACQUISITION SUMMARY

Free and open competitive procurements will be used to the maximum extent possible. Procurement is in accordance with normal procedures for R&D activities at the procuring centers. Among the procurement tools that have been and are expected to be used in the CAS Project are: NASA Research Announcements (NRA), NASA Cooperative Agreement Notices (CAN), and Requests for Proposals (RFP). These vehicles will result in grants, cooperative agreements and contracts. Existing vehicles such as the Scientific and Engineering Workstation Procurement II (SEWP II) contract may also be used. Interagency agreements may be used for joint R&D endeavors and the utilization of early prototype systems.

12.PROJECT DEPENDENCIES

12.1 Related Activities and Studies

The CAS Project works closely with elements of the IT Base Research and Technology Program. This program provides basic research in information systems upon which the CAS Project can build. The CAS Project also works closely with CoSMO. Through CoSMO, the CAS Project can transition its own results into operational use. The CAS Project also works closely with the HPCCP NREN Project to research the application of high-speed networking capability.

In addition to working with other information systems programs and projects, the CAS Project also works closely with other programs in the Aerospace Technology Enterprise. Since NASA's Aerospace Technology programs are important customers, the CAS Project works with the current programs to demonstrate to them and to reduce the risk to them of incorporating new information systems technologies.

There are no dependencies on these related NASA activities. There are, however, opportunities for synergy.

12.2 Related non-NASA Activities and Studies

As a part of the HPCC Program, the CAS Project works with other participants in the Federal High Performance Computing or Information Technologies R&D activities. CAS plays a lead role for NASA in the area of systems software and works with other agencies in this area.

The National Science Foundation (NSF) is a leader in the work on distributed heterogeneous computing and computational grids. The CAS Project works closely with participants in the NSF effort.

There are no dependencies on these non-NASA activities.

13.AGREEMENTS

13.1 NASA Agreements

There are no relevant internal NASA agreements.

13.2 Non-NASA Agreements

Relevant agreements to the CAS Project are listed below.

- Non-reimbursable Space Act Agreement between NASA ARC and The Boeing Co. for Advanced Aeroelastic Design Procedures, March 1997.
- Non-reimbursable Space Act Agreement between NASA LeRC (now GRC) and Allied Signal Engines et al. for Software Advancement, September 1997.
- MOU between NASA ARC and NSF in Distributed Heterogeneous Computing. May 1998.
- MOU between NASA and Silicon Graphics Inc. for collaborations in high-end computing, May 1999.
- Partially Reimbursable Space Act Agreement Between NASA Glenn Research Center and Stanford University for Integration of the National Combustion Code and the TFLO Code, April 2000.

14. PERFORMANCE ASSURANCE

14.1 General

The CAS Project deliverables will be assessed against the following metrics: performance, interoperability, portability, reliability, resource management, usability, and impact on Aerospace Technology missions and goals.

14.2 Reliability

Metrics are kept regarding the reliability of testbed hardware and software used in the CAS Project. Commercial off-the-shelf hardware and software are used to the greatest extent possible, however, the CAS Project often works with hardware and software that is less reliable than desired so that the reliability can be improved.

14.3 Quality Assurance

The CAS Project follows industry standards as well as applicable ISO 9001 procedures. In addition, an annual customer survey provides an opportunity for feedback on quality assurance.

14.4 Parts

The CAS Project is a computer research project. Its primary products are software and information about how to use information systems technology. The CAS Project is not involved with the stocking or development of parts.

14.5 Materials and Processes Control

The CAS Project is a computer research project. Its primary products are software and information about how to use information systems technology. The CAS Project does not deal in materials and processes control.

14.6 Performance Verification

Metrics are used to establish performance verification. The benchmarks and baselines provide the criteria against which to measure performance.

The CAS R&PT helps evaluate CAS technology for its desirability and usefulness in increasing simulation fidelity and reducing design cycle times in order to improve the capabilities, safety, efficiency, and operations of future aerospace vehicles and systems. These assessments form the foundation for annual updates and improvements to the CAS Project Plan which, in turn, allow periodic, re-balancing of the CAS Project Plan to focus attention on those items and issues that may be holding back exploitation of the emerging computational technology.

An annual survey is made of other Aerospace Technology Enterprise programs to assess the impact of the CAS Project on those programs and the level to which CAS technology has been disseminated within those programs. The Independent Annual Review process provides another measure of performance verification.

14.7 Contamination Allowance and Control

The CAS Project is a computer research project. Its primary products are software and information about how to use information systems technology. The CAS Project is not involved with contamination allowance and control.

14.8 Software Assurance

For software develop within the CAS Project, developers follow industry standards as well as applicable ISO 9001 procedures. Commercial off-the-shelf software is used to the greatest extent possible, however, the CAS Project often works with software that is less reliable than desired so that the reliability can be improved. In such cases, the CAS Project works closely with software vendors to correct deficiencies in software it uses.

14.9 Maintainability

Commercial off-the-shelf hardware and software are used to the greatest extent possible to facilitate maintainability. For software developed within the CAS Project, developers follow industry standards as well as applicable ISO 9001 procedures. They also work closely with those who will maintain the software to assure maintainability is considered in the design and development.

15. RISK MANAGEMENT

15.1 Introduction

Risk management is applied to the CAS Project to anticipate, mitigate, and control risks and focus project resources where needed. Risk management within this project follows the requirements and guidelines of NPG 7120.5a. CAS Project activities are planned to reduce the risk to other Aerospace Enterprise programs of adopting high-performance computing technology. Therefore, there is not just one single end product of the CAS Project, and in this respect, the CAS Project is different from many projects within other Focus Programs where the end product may be a complete aerospace vehicle. Demonstrating benefit to other programs is of primary importance. At the same time, CAS must enable the HPCC Program to meet program milestones, schedules, and resource commitments.

15.2 Overview of Process

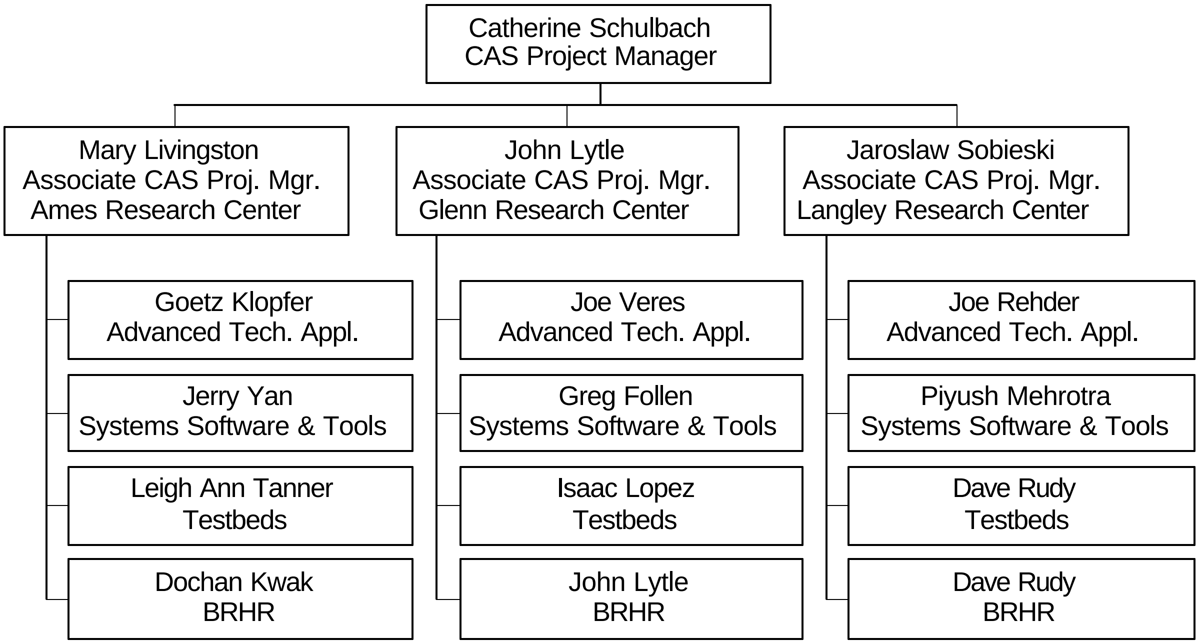
Risk management activities are carried out as part of the day-to-day activities of project personnel as well as during key project meetings. The risk management process includes the following activities:

- Risk Identification: a continuous effort to identify and document risks as they are found.
- Risk Analysis: an estimation of the probability, impact, and timeframe of the risks; classification into sets of related risks; and prioritization of risks relative to each other.
- Risk Planning: establish actions, plans, and approaches for addressing the risks, including developing mitigation plans for important risks.
- Risk Tracking: capturing, compiling, and reporting risk attributes and metrics that determine whether risks are being mitigated effectively and whether risk mitigation plans are being performed correctly.
- Risk Controlling: using status and tracking information to make a decision about a risk or risk mitigation effort.
- Risk Communication and Documentation: communicating and documenting the risk at all steps of the continuous risk management process.

Only the primary risks have any resources expended for mitigation. Other risks are watched or accepted.

15.3 Organization

More information on the organization of the CAS Project is available in section 5.1 of this document, but as summary is provided here for convenience. The CAS Project management team consists of the CAS Project Manager at Ames Research Center; Associate CAS Project Managers at Ames, Glenn, and Langley Research Centers, and Task Managers at each center that manage work breakdown structure elements at their corresponding centers. The project organization is shown on the following page:



15.4 Process Details

Risk management within the CAS Project is oriented around the need for the CAS Project to demonstrate benefit to other programs. Thus there are a number of concurrent activities aimed at different end-user organizations. These are frequently somewhat independent efforts that, taken together, enable the HPCC Program to meet program milestones, schedules, and resource commitments.

All CAS personnel are responsible for identifying risks. Risk database is reviewed at least yearly during major project reviews. A database of risk information is maintained by the CAS Project Office. Risks are classified according to impact, probability, and time frame. A three-level method is used for classification as shown below:

Impact: loss or effect on the project if the risk occurs

- High: One or more of the events listed below occurs.
  - Project will be cancelled.
  - Project will be unable to complete major Program-level milestone.
- Medium: One or more of the events listed below occurs.
  - Project funding will be significantly reduced.
  - Project will slip in accomplishment of major Program-level milestone.
  - Project milestone that supports Program-level milestone will be missed or delayed.
- Low: One or more of the events listed below occurs.
  - Project funding will be reduced by small amount.
  - Technical accomplishments do not meet expectations.

Probability: likelihood the risk will occur

- High: probability that it will occur is >70%.
- Medium: probability that it will occur is between 30% and 70%.
- Low: probability that it will occur is <30%.

Time frame: period within which action must be taken to mitigate the risk

- Near-term: project must take action or will be impacted by the risk in the next 6 months.
- Mid-term: project must take action or will be impacted by the risk in the next 6 months to one year.
- Far-term: project need not take action or will not be impacted by the risk in the next year.

A summary of the primary risks and mitigation approaches for the CAS Project is shown in Table 15-1.

Table 15-1: Summary of CAS Risk Assessment.

Risk	**Risk Impact**	**Risk Probability**	**Risk Probability Mitigation Processes**
If critical OAT Programs do not express value of CAS, funding may be cut or project may be terminated.	High	Medium	• Engage critical programs in identifying priority needs and work closely with them • Review selections with HPCCP, HPCC EC and HPCC EC WG • Review, and if necessary, realign application foci on periodic basis • Advocate benefits to customers • Publicize Project accomplishments
If requirements for CAS Project change, CAS work may be viewed as unimportant if it is not realigned	High	Medium	• Involve customers in technical implementation, from concept through delivery and work closely with them • Document requirements • Monitor potential changes in customer requirements and document changes • Establish and follow engineering/ development plans • Include customer in discussions involving prioritization of activities or redirection of technical approaches
If partners do not meet commitments CAS may be unable to meet its commitments	Medium	Medium	• Formal joint plans and teams • Formal MOUs and MOAs • Periodic and regular management reviews • Develop contingency plans
If schedule and performance	Medium	Medium	• Regular tracking and reporting of progress • Set goals that exceed minimum success

commitments are not met, the project may lose funding or be terminated			criteria • Develop and implement contingency plans
If testbeds belong to multiple programs, requirements may get out of control.	Medium	Medium	• Establish inter-project communication and coordination processes • Establish requirements management process
Changes in another HPCCP project may affect CAS ability to meet its commitments.	Medium	Low	• Establish inter-project communication and coordination processes • Develop contingency plans
If CAS projects are duplicative of or not coordinated with similar projects, CAS work may be seen as irrelevant.	Medium	Low	• Facilitate inter-organization communication • Track activities of HPC community • Realign resources to remove duplication
If there is no capital investment funding within NASA, access to major computational facilities may be unavailable.	Medium	Low	• Participate in development of NASA strategy for supercomputing. • Establish partnerships with other programs and organizations, including those external to NASA • Develop MOUs/MOAs to formalize relationships for access to facilities
If CAS activities are not coordinated, one activity could negatively impact another project.	Medium	Low	• Facilitate intra-project communication. • Conduct regular meetings/telecons. • Clarify and document roles and responsibilities
If key personnel leave, technical projects will not meet performance expectations.	Medium	Low	• Documentation of project requirements and implementation plans • Backups for key personnel
If CAS does not leverage commercial technology, resources may be used ineffectively.	Medium	Low	• Continual use and evaluation of commercial technology • Periodic surveys of commercial technology • Participate in HPC community and track activities of peer organization

Risks are reviewed during development of changes to the project plan, during annual reviews, and during periodic reviews keyed to the accomplishment of specific milestones. Updates are performed by the CAS Project office.

15.5 Resources and Schedule

Risks are reviewed during development of changes to the project plan, during annual reviews, and during periodic reviews keyed to the accomplishment of specific milestones

15.6 Documentation of Risks

A database of risk information is maintained by the CAS Project Office.

15.7 Methodology

Should project descope be required, the Project Manager, Associate Project Managers, and Task Managers will review options and develop a revised plan for operations. The continuous risk management process will apply to the new scope of operations.

The descope process begins with establishing the requirements for descoping the project , such as identifying whether the reduction is small, medium, or large and whether the descoping is one-time or permanent. Then a current status of budget and resources will be prepared to help identify available options (e.g., if descope requirement occurs late in the year, there are fewer budget options because money will already have been spent). Next a list of options and their impacts will be prepared. These options will be evaluated and placed in priority order based on impact to the CAS Project, HPCC Program, and PCA milestones. These will form the basis of recommendations for descoping, which must be approved in accordance with established procedures for project changes (reference section 9.1)

16. ENVIRONMENTAL IMPACT

The CAS Project is a computer research project. Its primary products are software and information about how to use information systems technology. The CAS Project does not develop new parts, materials, vehicles, or facilities. The CAS Project does not require the building of any new facilities. On occasion, the installation of a new computer system may raise environmental concerns (as did the use of florinert to cool older Cray systems), and these are dealt with by the performing organization and its procedures. However, there are no anticipated environmental issues in the CAS Project.

17. SAFETY

The CAS Project is a computer research project. Its primary products are software and information about how to use information systems technology. However, there are sometimes actions such as computer installations that raise safety issues. These safety issues are dealt with by the performing organization and its procedures. The CAS Project Manager works with the performing organizations to assure the existence of appropriate safety plans and procedures.

18. TECHNOLOGY ASSESSMENTS

CAS is a computer research project that pursues technologies that are between one and ten years from maturity. Applications in aerospace are used as drivers of the computational technology research, providing the requirements context for the work that is done.

CAS conducts TRL 2 - 6 research activities intended to prove feasibility and develop and demonstrate computing technologies for eventual introduction into NASA operations through operational entities like CoSMO or into the aerospace community.

Periodic assessments of technology are performed as part of determining specific information technology approaches to meeting requirements.

19. COMMERCIALIZATION

Commercialization opportunities are exploited through Space Act Agreements, Cooperative Research Agreements and Memoranda of Understanding with industry. Joint projects in high risk areas are pursued on a cost-sharing basis with industry and in close collaboration with government laboratories and academia. The CAS Project fosters horizontal partnerships between NASA and multiple companies within the aerospace sector. The CAS Project also fosters the vertical integration of collaborative teams between hardware suppliers, third-party software vendors, and members of the US aerospace community. The CAS Project sponsors and conducts technical meetings and workshops and promotes the publication of scientific and technical papers to maintain the flow of technology from NASA to industry and academia.

20. REVIEWS

As part of the HPCC Program, the CAS Project is subject to Independent Annual Reviews. The Independent Annual Reviews are conducted in accordance with established policies and procedures.

A technical review of the CAS Project is conducted annually by the HPCC Program Manager. These reviews are typically conducted at the end of the fiscal year at the lead-project center but may involve on-site reviews. The reviews are conducted to evaluate the progress of the project and give critical feedback to the project managers. In addition to appropriate NASA personnel, representatives from other federal agencies, academia and industry may be invited to participate. Reviews are conducted in accordance with established policies and procedures.

The CAS Project Manager and Associate Project Managers submit reports and present reviews periodically to evaluate technical and administrative progress on the CAS Project. They support the HPCC Program Manager in developing material for quarterly reviews for the Office of Aerospace Technology, the lead-center Director, and the Program Management Council. They also develop CAS reports for the HPCC Program Annual Report and for Quarterly Reports.

The CAS Project Manager conducts regular annual reviews as well as periodic reviews keyed to the accomplishment of specific milestones. These periodic reviews may include system or software requirements reviews, design reviews, software reviews, and readiness or acceptance reviews.

21. TAILORING

This CAS Project Plan conforms to the NASA Program and Project Management Processes and Requirements (NPG 7120.5A), with adaptations appropriate to an ongoing and relatively small activity. Sections on acquisition summary, performance assurance, environmental impact, safety, technology assessments, commercialization, and reviews are tailored to the nature of this technology program.

22. CHANGE LOG

22.1 Changes from Project Inception (1992)

1. **January 1994.** Additional CAS work content on the use of distributed workstation clusters for design was added in response to expressed need from airframe and propulsion industry.
2. **February 1997.** Cuts to CAS budget as a result of responding to Presidential initiative to develop NGI.
3. **June 2000.** Revision of Project plans to conform to HPCC Program changes reflecting Phase II organization and program objectives of the HPCCP activity.

Appendix A: Glossary

ARC	Ames Research Center
ATA	Advanced Technology Applications
CAN	Cooperative Agreement Notice
CAS	Computational Aerospace Sciences
CIC	Computing, Information and Communications
CoSMO	Consolidated Supercomputing Management Office
ESS	Earth and Space Sciences
FTE	Full Time Equivalent
GRC	Glenn Research Center
HPCCP	High Performance Computing and Communications Program
IT	Information Technology (Research and Technology Base Program)
LaRC	Langley Research Center
LeRC	Lewis Research Center, now Glenn Research Center
LT	Learning Technologies
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NGI	Next Generation Internet
NPD	NASA Policy Directive
NPG	NASA Procedures and Guidelines
NREN	NASA Research and Education Network
NRA	NASA Research Announcement
NSF	National Science Foundation
PCA	Program Commitment Agreement
PMC	Program Management Council (NASA HQ Level)
R&PT	Review and Planning Team
R&D	Research and Development
RFP	Request for Proposal
TRL	Technology Readiness Level
WBS	Work Breakdown Structure